FORM PTO-1390 (REV 5-93) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: 32431/DOB/lp

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 1.5): still unknown 09/308962

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/EP97/06619	November 27, 1997	December 2, 1996

TITLE OF INVENTION: METHOD FOR INCREASING THE BEARING CAPACITY OF FOUNDATION SOILS FOR BUILDINGS

APPLICANT(S) FOR DO/EO/US: Carlo CANTERI

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [XX] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [XX] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1)
4. [XX] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. [XX] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [XX] is transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] has been transmitted by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US)
6. [ ] A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. [XX] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [ ] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [XX] have not been made and will not be made.
8. [ ] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. [XX] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). (unsigned)
10. [ ] A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. [XX] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3 28 and 3 31 is included.
13. [XX] A FIRST preliminary amendment.
    [ ] A SECOND or SUBSEQUENT preliminary amendment.
14. [ ] A substitute specification.
15. [ ] A change of power of attorney and/or address letter.
16. [XX] Other items or information: redrafted claims 15 to 28 for entering the preliminary amendment and new abstract of the disclosure

U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
Still unknown	PCT/EP97/06619	32431/DOB/1p

17. ☐ The following fees are submitted:	CALCULATIONS	PTO USE ONLY
Basic National Fee (37 CFR 1.492(a)(1)-(5)):		
Search Report has been prepared by the EPO or JPO..... $840.00		
International preliminary examination fee paid to USPTO (37 CFR 1.482) $670.00		
No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2))..$700.00		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37CFR 1.445(a)(2)) paid to USPTO..... $970.00		
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4)..... $90.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 970.=	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

Claims	Number Filed	Number Extra	Rate	
Total claims	14 -20 =		X $ 18.=	$
Independent Claims	1 -3 =		X $ 78.=	$
Multiple dependent claims(s) (if applicable)			+ $ 260.=	$
TOTAL OF ABOVE CALCULATIONS =				$ 970.=
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28). (to follow)				$ 485.=
SUBTOTAL =				$ 485.=
Processing fee of $130.00 for furnishing the English translation later the ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$
TOTAL NATIONAL FEE =				$ 485.=
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$ 40.=
TOTAL FEES ENCLOSED =				$ 525.=
			Amount to be: refunded	$
			charged	$

a. ☐ A check in the amount of $_____ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 13-3860 in the amount of $ 525.= to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 13-3860. A duplicate copy of this sheet is enclosed.

NOTE: **Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.**

Milano, Italy
May 21, 1999

SEND ALL CORRESPONDENCE TO:

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Tel. 02-86.92.442

Daniel O'Byrne
SIGNATURE

Daniel J. O'BYRNE
NAME

36,625
REGISTRATION NUMBER

Form PTO-1390 (REV 5-93)

PTO/SB/ 10 (6-95) (modified)
Approved for use through 07/31/96. OMB 0651-0031
Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

VERIFIED STATEMENT CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) & 1.27(c))--SMALL BUSINESS CONCERN	Docket Number (Optional): 32431/DOB/cb

Applicant or Patentee: Carlo CANTERI

Application or Patent No.: 09/308,962

Filing Date or Issue Date: May 27, 1999

Title: METHOD FOR INCREASING THE BEARING CAPACITY OF FOUNDATION SOILS FOR...

I hereby declare that I am

[ ] the owner of the small business concern identified below:

[x] an official of the small business concern empowered to act on behalf of the concern identified below:

NAME OF SMALL BUSINESS CONCERN PURE LIFE FOUNDATION

ADDRESS OF SMALL BUSINESS CONCERN Aeulestrasse, 38
9490 VADUZ - LIECHTENSTEIN

I hereby declare that the above identified small business concern qualifies as a small business concern as defined in 13 CFR 121.12, and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees to the United States Patent and Trademark Office, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the invention described in:

[ ] the specification filed herewith with title as listed above.

[x] the application identified above.

[ ] the patent identified above.

If the rights held by the above identified small business concern are not exclusive, each individual, concern or organization having rights in the invention must file separate verified statements averring to their status as small entities, and no rights to the invention are held by any person, other than the inventor, who would not qualify as an independent inventor under 37CFR 1.9(c) if that person made the invention, or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d), or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern or organization having any rights in the invention is listed below:

[X] No such person, concern, or organization exists.

[ ] Each such person, concern or organization is listed below:

_____

_____

Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF PERSON SIGNING Paolo IOB

TITLE OF PERSON IF OTHER THAN OWNER Proxy Holder

ADDRESS OF PERSONS SIGNING Freihofstrasse 31 - CH-8880 WALENSTADT (SAN GALLO)-SWITZERLAND

SIGNATURE _____ DATE August 24, 1999

Docket No. 32431/DOB/lp

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Assignor	:	Carlo CANTERI
Assignee	:	PURE LIFE FOUNDATION
Ser. No.	:	still unknown
Filed	:	still unknown
For	:	"METHOD FOR INCREASING THE BEARING CAPACITY OF FOUNDATION SOILS FOR BUILDINGS"
A.U.	:	still unknown
Examiner	:	still unknown

Hon.
The Commissioner of Patents and Trademarks
Box P.C.T.
Washington D.C. 20231 - U.S.A.

PRELIMINARY AMENDMENT

Sir,

please enter the following preliminary amendment in the above-identified Application:

substitute the original claims 1 to 14 with the enclosed redrafted claims 15 to 28;

substitute the original abstract with the enclosed redrafted abstract of the disclosure where merely the numeral references have been deleted.

It is to be noted that the newly submitted claims 15 to 28 and the new abstract of the disclosure do not comprise any new matter and are merely aimed at meeting U.S. filing requirements.

Respectfully submitted

Daniel J. O'BYRNE
(Reg. No. 36,625)
Agent for the Applicant
Via Meravigli, 16
20123 MILANO - ITALY

Milan, Italy
May 21st, 1999

WHAT IS CLAIMED IS:

15. A method for increasing the bearing capacity of foundation soils for buildings comprising: providing a plurality of holes spaced from each other deep in the soil; injecting into the soil, through said holes, a substance which expands as a consequence of a chemical reaction; producing compaction of the soil contiguous to the injection zone due to the expansion of said substance injected into the soil, further comprising the step of constantly monitoring the level of the soil and/or building overlying the injection zone to detect the moment when the building and/or the soil surface, overlying said injection zone, begins to raise which is the moment in which the compaction of the soil has reached levels generally higher than the required minimum value, and wherein the expansion of the injected substance is very fast with a potential increase in volume of the expanded substance being at least five times the volume of the substance before expansion.

16. A method according to claim 15, wherein the injecting step is repeated at different depth levels for producing compaction of the masses or layers of treated soil.

17. A method according to claim 16, wherein said different depth levels are spaced by approximately 1 m from each other, at each level a greater bearing capacity than the required one being obtainable.

18. A method according to claim 15, wherein said monitoring step is performed with a laser level apparatus.

19. A method according to claim 16, wherein said holes are provided vertically, the injection steps being performed continuously along rising columns wherein tree-like shapes are formed with a very irregular configuration with protrusions, bumps and projections of considerable size produced by different resistance to compaction of the soil, and by the presence of interstices or fractures in the soil.

20. A method according to claim 19, wherein an entire thickness of the

soil layers which are compressible or have low bearing capacity is treated so as to perform consolidation up to the solid horizon of the layers having a sufficient bearing capacity regardless of the depth at which the solid horizon is located.

21. A method according to claim 20, wherein the expandable substance is selected from substances adapted to produce immediate expansion, such as a substance comprising a mixture of polyols and an isocyanate MDI.

22. A method according to claim 21, wherein the expandable substance comprises a mixture of two components, the first being a polyether polyol and/or a polyester polyol, a catalyst and water, and the second being the isocyanate MDI.

23. A method according to claim 19, wherein the distance between two adjacent holes is between 0.5 m and 3 m.

24. A method according to claim 23, wherein said holes are provided at an angle with respect to the vertical.

25. A method according to claim 16, wherein the injection step comprises several active injection phases alternated with suitable pauses.

26. A method according to claim 15, wherein the injection substance is heated just before the injection step.

27. A method according to claim 22, wherein the water content is of 3.44%, by weight.

28. A method according to claim 25, wherein in the injection step, tubes are used through which the expandable substance is injected into the soil, the tubes having an inner diameter of about 10 mm.

ABSTRACT OF THE DISCLOSURE

A method for increasing the bearing capacity of foundation soils for buildings consisting in providing a plurality of holes spaced from each other deep in the soil, and in injecting into the soil, through the holes, a substance which expands as a consequence of a chemical reaction, with a potential increase in volume of at least five times the volume of the substance before expansion; the expansion of the substance injected into the soil producing compaction of the contiguous soil.

APPLICATION

FOR

UNITED STATES OF AMERICA

* *

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

Be it known that I,

Carlo CANTERI
Italian citizen
of BRUNATE - ITALY

have invented certain improvements in

"METHOD FOR INCREASING THE BEARING CAPACITY OF FOUNDATION SOILS FOR BUILDINGS"

of which the following description in connection with the accompanying drawings is a specification, like reference characters on the drawings indicating like parts in the several figures.

BACKGROUND OF THE INVENTION

The present invention relates to a method for increasing the bearing capacity of foundation soils for buildings.

Any building requires the foundation soil to have a sufficient bearing capacity to support it. Otherwise, the settling of the foundation soil leads to the failure of the overlying building, regardless of whether the settling occurs in the uppermost or in the deep layers.

Before erecting any building, the bearing capacity of the soil is therefore estimated according to the weight or load which the building will apply to the soil, even using, if necessary, appropriate soil research, such as for example geological and geotechnical research.

In order to ensure the stability of the structure, the optimum dimensions of the foundations and their rigidity are calculated and the depth of the foundations is also determined, adequately balancing their weight in relation to the bearing capacity of the soil and always maintaining a good safety margin. In case of error, the building may in fact fail.

Often, however, the bearing capacity of the foundation soil is not sufficient, since the soil is compressible, as in the case of filled-in land, non-consolidated land, land with decomposing organic layers, peaty land, swampy land, land with considerable variations in water content, flooded or washed-out land with voids or with non-uniform or insufficiently aggregated masses, land with interstitial voids, et cetera; or the building is very heavy and requires a greater bearing capacity than the actual bearing capacity of the foundation soil.

Various conventional systems ensure in any case the stability of the building. Generally, these systems tend to directly transfer the weight of the building to the deeper and adequately solid soil layers or to spread the load over a wide ground surface, such as for example the method consisting in driving piles or micropiles and the like into the foundation soil. This

method can be used both before and after construction.

Of course, the driving of piles and micropiles or the like after the construction of the building is extremely complicated and expensive.

Conventional methods also cope with any subsidence of the building after its construction, such as for example the method described in US patent 4,567,708, which entails the injection of an expandable substance beneath the building to fill the interstices which have formed and have caused the subsidence and in order to recover the subsidence of the building, or other lifting methods.

In the method disclosed in the above-cited patent, as well as in other lifting systems, however, the foundation soil is not treated; at the most, one acts on the surface layers of the soil, and therefore if the underlying soil has not settled enough, further subsequent subsidence of said building will occur over time.

A method for ground consolidation using, an expandable substance, in which the expansion time is controlled to be slow or very slow, is known from the document DE-A-33 32 256.

SUMMARY OF THE INVENTION

A principal aim of the present invention is to solve the above problems by providing a method capable of ensuring the stability of buildings by adequately treating the foundation soil in order to increase its bearing capacity.

Within the scope of this aim, an object of the present invention is to provide a method which does not require the use of cement, concrete, or metal structures driven into the ground, such as piles, micropiles, cement injections, very deep foundations, etcetera.

Another object of the present invention is to provide a method which is simple and easy to perform and can be adopted to increase the bearing capacity of foundation soils both before and after construction of the building.

This aim, these objects, and others which will become apparent hereinafter are achieved by a method for increasing the bearing capacity of foundation soils for buildings, according to the present invention, comprising the steps set forth in claim 1.

BRIEF DESCRIPTION OF THE DRAWINGS

Further characteristics and advantages of the present invention will become apparent from the following detailed description of a preferred but not exclusive embodiment of the method according to the invention, illustrated only by way of non-limitative example in the accompanying drawings, wherein:

figure 1 is a schematic view of the injection of the expandable substance through holes formed in the soil;

figures 2 and 3 are views of the result of the expansion of the expandable substance when the substance is injected whilst the tube used for injection is gradually retracted upwards, respectively with pauses at intermediate depth levels or with a continuous motion;

figure 4 is a view of the result of the expansion of the injected substance in the case of sequential injections performed with different tubes, inserted in different holes, in points spaced from each other and at different depths;

figure 5 is a schematic view of an injection operation, according to the invention, with constant monitoring of the sinking recovery of a building foundation;

figures 6-8 are comparative diagrams of dynamic penetrometric tests carried out on a soil area treated according to the invention;

figure 9 is a sectional view of a soil area treated in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The method according to the present invention substantially consists in forming in the soil a plurality of holes 1 which, if one must act on

existing buildings, may or may not pass through the foundation, at different depths and preferably with a distance between two contiguous holes 1 which can vary between 0.5 m and 3 m.

The holes 1 can have variable dimensions according to requirements and can be provided substantially vertically or at an angle with respect to the vertical.

The depth of the holes may also vary according to requirements, as will become apparent hereinafter.

Tubes 2 are then inserted or driven into the holes 1 and a substance 3 expanding as a consequence of a chemical reaction between the components, with a potential volume increase of at least five times the volume of the substance before expansion, is injected into the soil through said tubes. The expression "potential volume increase" relates to the volume increase of the substance as a consequence of an expansion occurring unhindered at atmospheric pressure.

High expansion coefficients of 20-25 times the initial volume or even higher such as 30-33 may be preferred.

The expandable substance is conveniently constituted by a mixture of expandable polyurethane foam, preferably a closed-cell polyurethane foam. This substance can be constituted, for example, by a two-part foam mixed inside a mixing unit 4 connected to the injection tubes 2. The first component can be a mixture of polyols comprising a polyether polyol and/or a polyester polyol, a catalyst, such as RESINOL AL 643 produced by the Dutch company Resina Chemie, and water. The water in the composition may be 3.44% by weight. The second component can be an isocyanate MDI, such as URESTYL 10 manufactured by the same company. The mixing of these two components produces an expandable polyurethane foam the density whereof, at the end of expansion, varies according to the resistance opposed by the soil adjacent to the injection region.

The mixture may expand up to about 33 times its initial volume and the reaction time is of about 3-6 seconds, as it appears from the technical specifications of the manufacturer.

It is of course also possible to use other expandable substances having similar properties without thereby abandoning the scope of the protection of the present invention.

According to requirements, the expandable substance can be injected through the holes 1 formed beforehand in the soil in a single injection step, as shown in figures 1, 2, and 3, starting from the bottom, whilst the injection tube is gradually retracted upwards, optionally with intermediate pauses, as shown in figure 2, so as to obtain different columns of hardened and expanded substance, or the substance can be injected, optionally by performing sequential injections at fixed and different depths in points which are three-dimensionally and uniformly spaced from each other so as to obtain regions of expanded and hardened substance within the foundation soil, as shown in particular in figure 4, according to requirements and according to the geological characteristics of the soil. In this last case, the tubes used for injection are left in the soil.

Once the substance 3 has been injected, since it has also penetrated in any voids and fractures of the soil thanks to its fluidity, expanding with great force and speed in all directions, it generates a force which compacts and compresses the soil all around, eliminating by compression or filling all voids and microvoids, even extremely small ones, expelling most of the water impregnating the soil, possibly agglomerating loose parts (granules and noncohesive parts) until a mass of soil is obtained which, throughout the treated layer, can no longer be compressed in relation to the weight that it has or will have to bear.

It should be noted that the expandable substance injected at different depths, in appropriately calculated points having a specific distance from each other, or along ascending lines, during expansion automatically

flows towards the more compressible points, which as such offer less resistance to the expandable substance. In this manner, the regions which most need treating are automatically treated more intensely, without leaving spaces with untreated regions.

The immediate nature of the expansion of the injected substance also allows to delimit the expansion region rather precisely, thus allowing to localize very well, in the intended points, the effect to be produced. The intense pressure applied by the injected substance to the surrounding soil is in fact due to the expansion caused by the chemical reaction and is not caused by hydraulic pressure. The expandable substance is injected through a hydraulic pressure which, however, only has the purpose of introducing the substance in the chosen points.

The immediate reaction of the injected substance, in terms of expansion and curing, prevents its migration to faraway areas, where a slow reacting substance may instead arrive. In fact, the slower the expansion reaction is the farther the substance arrives, to the detriment of the precise delimitation of the expansion effect and with consequent increase of the injection substance consumption.

Advantageously, since in the conditions of the invention the consolidation has a focused effect with low substance consumption, injection tubes may be used providing sufficient injection substance flow rates which have an inner diameter, for example of 10 mm, thus being easily insertable into and retractable from the soil. Tube diameters being smaller or larger by some millimeters are also usable. Anyway employing tubes with much larger diameters, of about 2 cm or more, difficult to drive into the soil, for obtaining high substance flow rates is not necessary.

To efficiently localize the effect of the consolidation, the injection may be carried out, with intermediate pauses. For example injection periods of 15 seconds may be alternated with pauses of 1-2

seconds or even longer. The durations of the active injection and respectively of the alternating pause periods are in fact selectable to be the more suitable considering factors such as the injection depth, the injection substance composition the length and the cross section of the injection tubes.

For obtaining a more rapid expansion reaction of the injected substance without having to switch to other compositions, where necessary, it is possible to raise by heating the temperature of the substance just before the injection operation.

As regards the hole depth, two different methods can be performed.

A first method consists in treating the entire thickness of the soil layers which are compressible or have a low bearing capacity, so as to perform consolidation up to the solid horizon of the layers having a sufficient bearing capacity, regardless of their depth. The solid horizon can be detected by means of geotechnical research conducted on the soil.

The second method instead consists in treating a layer of soil which, for reasons related to technical and/or economic convenience, does not reach down to the identified solid horizon, which might be located at an excessive depth, but is in any case thick enough to distribute the overlying weight over a wider surface. The layer of soil treated with the method according to the invention, by constituting a sufficiently compact, solid, and in any case light layer, can be effectively and broadly supported by the underlying layers of soil, even if those layers would not otherwise have a sufficient bearing capacity.

Until now, injection depth of up to 6 m have been successfully experimented, but with adapted tube cross-sections and accurately controlled substance injection flow rates, greater injection depths may be attained.

The expansion of the injected substance following the chemical reaction of its components is very fast and develops a very high

expansion force: up to 40 tons per square meter or even higher.

During injection, the level of the overlying building or of the surface soil can be constantly monitored by means of a laser level 5 or another system (see figure 5). When the apparatus 5 indicates that the building or the soil surface begins to rise, this generally means that the compaction of the soil, in three dimensions all around the injection point, has reached very high levels which are generally higher than the required minimum values.

Through the constant monitoring operation, the precise moment when the soil begins rising at a precise spot, due to the narrowly focused expansion force, and further the exact amount of the lifting are accurately detected and may be controlled in real time.

The mass of injected substance, by reacting chemically, in fact expands with great force in all directions, and when the apparatus detects even a small rise at the surface, this means that the expandable substance has encountered less resistance in expanding in the vertical direction with respect to all other directions and that therefore the soil lying below and around the injected substance withstands and "rejects" all the weight (which is dynamic and therefore multiplied) not only of the entire mass of soil (and of any building) which rests statically thereon, but also of all the surrounding mass displaced (by friction and cohesion) at a load diffusion angle which is usually calculated at around 30° and is simply inverted. The raised soil, too, undergoes compression.

By repeating this operation at different depth levels (spaced by approximately 1 meter from each other, but variably according to the kind of soil and to the bearing capacity to be obtained), at each level, a greater bearing capacity is obtained than the required one. By acting in this last manner and by performing continuous injections along rising columns, wherein tree-like shapes are formed with a very irregular configuration, with protrusions, bumps, and projections even of

considerable size produced by the different resistance of the soil to compaction and to the possible presence of interstices or fractures in the soil, in any case the entire mass and the treated layer of soil are compressed, packed and compacted; the water content decreases considerably; and the soil becomes a valid foundation soil adapted to stably support the building which lies above or is to be built.

The expandable substance can have a density varying indeed according to the resistance opposed by the surrounding soil to its expansion. In most cases, density can vary between 100 kg/m^3 and 300 kg/m^3. There may also be higher densities, since the density of the expanded substance is directly proportional to the resistance which it encounters to its expansion. The compression resistance of the expanded substance itself is a function of density.

A substance with a density of 100 kg/m^3 offers a resistance of approximately 14 kg/cm^2, whilst at a density of 300 kg/m^3 compression resistance is approximately 40 kg/cm^2. These values are far higher than those normally required for a foundation soil. In any case, where higher compression resistance values are required, even at different depths of the same soil, there is also a greater weight and therefore a higher resistance to expansion; accordingly, a denser and therefore stronger material forms automatically.

In any case, it is possible to momentarily add weight to a soil surface or to a building.

In practice, the injected and hardened expanded substance does not support the overlying building on its own, though helping to achieve this purpose; the weight of the building is effectively supported by the foundation soil treated with the method according to the invention.

In practice it has been observed that the method according to the invention fully achieves the intended aim and objects, since it allows, in a very simple, rapid, effective, and final manner, to increase the bearing

capacity of foundation soils until they fully comply with construction requirements.

Typically, in what seems to be a general trend in ground consolidation techniques, see for example the document DE-A-33 32 256, a very rapid expansion, with very high expansion coefficients, creating rapidly increasing pressures in the treated soil, is purposely avoided, since it was shown to provoke unwanted, mainly vertical, fissures in the treated mass ground.

In the conditions of the invention, however, it has surprisingly been noted that fissures occurring between soil masses, not only do not affect the soil compaction, but can in fact be advantageously exploited.

Technical tests and studies, carried out on built lots where the consolidation method of the invention has been used, have demonstrated that the expansion of the injected material occurs first in directions where the soil offers less resistance, but only for a limited extent. In the case of a built spot this happens, in the first place, laterally to the foundation and not in the vertical direction, where the weight of the building acts.

Only after the ground compaction degree is such as to provide a resistance to the lateral expansion forces well exceeding the weight force exerted by the building, a vertical force is obtained such as to raise the foundation and the building. In fact it is not only the weight of the building which has to be compensated for, but also other resistant forces, such as part of the weight of adjacent constructions, lateral friction forces and the flexural strength of the built structure itself.

While an immediate reaction of the injected material, in terms of expansion and solidification, may provoke indeed fissures between soil masses forced to move with respect to each other by rapidly increasing, strong forces, a certain quantity of the injected substance appears in fact to fill up the fissures so as to "weld" satisfactory the soil masses, at least in the area to be consolidated, which is immediately close to the

injection site and under the foundation of the built structure. For exemplification see figure 9, where a "welded" fissure may clearly be seen.

Penetrometric tests, the results whereof are shown in the diagrams of figures 6-8, have been carried out both under built spots treated with the consolidation method according to the invention, after a soil lifting has been sensed by the level apparatus , and laterally thereto, in close vicinity, at about 20 cm from the foundation.

From these diagrams showing comparatively the soil bearing capacity before consolidation (the not shadowed prisms) and after the consolidation (the shadowed prisms), clearly appears that the main consolidation occurs under the foundation, between 120 and about 300 cm of depth (figure 6), while at only 20 cm laterally from the foundation, the consolidation appears, at the same depths as before, significantly diminished (figure 7).

It is believed that this clearly shows the focused effect of the consolidation carried out according to the invention which practically provides a noteworthy reinforcement of mainly the soil under the foundations.

The diagram of figure 8, drawn in the condition where an amount of expandable substance has been injected which has not provoked any detectable lifting reaction of the soil under the building foundation, shows that in fact, laterally, at only 20 cm from the foundation, practically no effective soil compaction has occurred which would have allowed generation of the vertical force necessary to the lifting and thereby also limiting the area where fissures may occur.

The method according to the invention has successfully been applied to consolidate the ground and to compensate subsidences under heavily loaded foundations in airports, in industrial and commercial constructions as well as under very old, historic buildings and at archaeological sites.

Checkings of treated sites have been made recently, and have all given

satisfactory results. The inspections have been carried out in accordance with a procedure approved by the French Control Institute SOCOTEC consisting substantially in injecting, at a site selected by an inspector in a treated zone, at random, a small quantity of the injection substance (about 20% of the quantity initially injected). The result has been considered positive if the injection triggered at least a minimum lifting effect of the soil surface.

The method thus conceived is susceptible of numerous modifications and variations, all of which are within the scope of the inventive concept; all the details may furthermore be replaced with other technically equivalent elements.

CLAIMS

1. A method for increasing the bearing capacity of foundation soils for buildings comprising: providing a plurality of holes (1) spaced from each other deep in the soil; injecting into the soil, through said holes, a substance (3) which expands as a consequence of a chemical reaction; producing compaction of the soil contiguous to the injection zone due to the expansion of said substance injected into the soil, characterized in that it further comprises the step of constantly monitoring the level of the soil and/or building overlying the injection zone to detect the moment when the building and/or the soil surface, overlying said injection zone, begins to raise which is the moment in which the compaction of the soil has reached levels generally higher than the required minimum value, and in that the expansion of the injected substance is very fast with a potential increase in volume of the expanded substance being at least five times the volume of the substance before expansion.

2. A method according to claim 1, characterized in that the injecting step is repeated at different depth levels for producing compaction of the masses or layers of treated soil.

3. A method according to claim 2, characterized in that said different depth levels are spaced by approximately 1 m from each other, at each level a greater bearing capacity than the required one being obtainable.

4. A method according to any of the preceding claims, characterized in that said monitoring step is performed with a laser level apparatus (5).

5. A method according to any of the preceding claims, characterized in that said holes (1) are provided vertically, the injection steps being performed continuously along rising columns wherein tree-like shapes are formed with a very irregular configuration with protrusions, bumps and projections of considerable size produced by different resistance to compaction of the soil, and by the presence of interstices or fractures in the

soil.

6. A method according to any of the preceding claims, wherein the entire thickness of the soil layers which are compressible or have low bearing capacity is treated so as to perform consolidation up to the solid horizon of the layers having a sufficient bearing capacity regardless of the depth at which the solid horizon is located.

7. A method according to any of the preceding claims, wherein the expandable substance is selected from substances adapted to produce immediate expansion, such as a substance comprising a mixture of polyols and an isocyanate MDI.

8. A method according to claim 7, wherein the expandable substance comprises a mixture of two components, the first being a polyether polyol and/or a polyester polyol, a catalyst and water, and the second being the isocyanate MDI.

9. A method according to any of the above claims, characterized in that the distance between two adjacent holes is between 0.5 m and 3 m.

10. A method according to any of the claims 1-4 and 6-9, characterized in that said holes (1) are provided at an angle with respect to the vertical.

11. A method according to claim 1, wherein the injection step comprises several active injection phases alternated with suitable pauses.

12. A method according to one or more of the preceding claims, wherein the injection substance is heated just before the injection step.

13. A method according to claim 8, wherein the water content is of 3.44%, by weight.

14. A method according to one or more of the preceding claims, wherein in the injection step, tubes (2) are used through which the expandable substance is injected into the soil, the tubes having an inner diameter of about 10 mm.

METHOD FOR INCREASING THE BEARING CAPACITY OF FOUNDATION SOILS FOR BUILDINGS

ABSTRACT OF THE DISCLOSURE

A method for increasing the bearing capacity of foundation soils for buildings consisting in providing a plurality of holes (1) spaced from each other deep in the soil, and in injecting into the soil, through the holes (1), a substance (3) which expands as a consequence of a chemical reaction, with a potential increase in volume of at least five times the volume of the substance before expansion; the expansion of the substance (3) injected into the soil producing compaction of the contiguous soil.

(Figure 1)

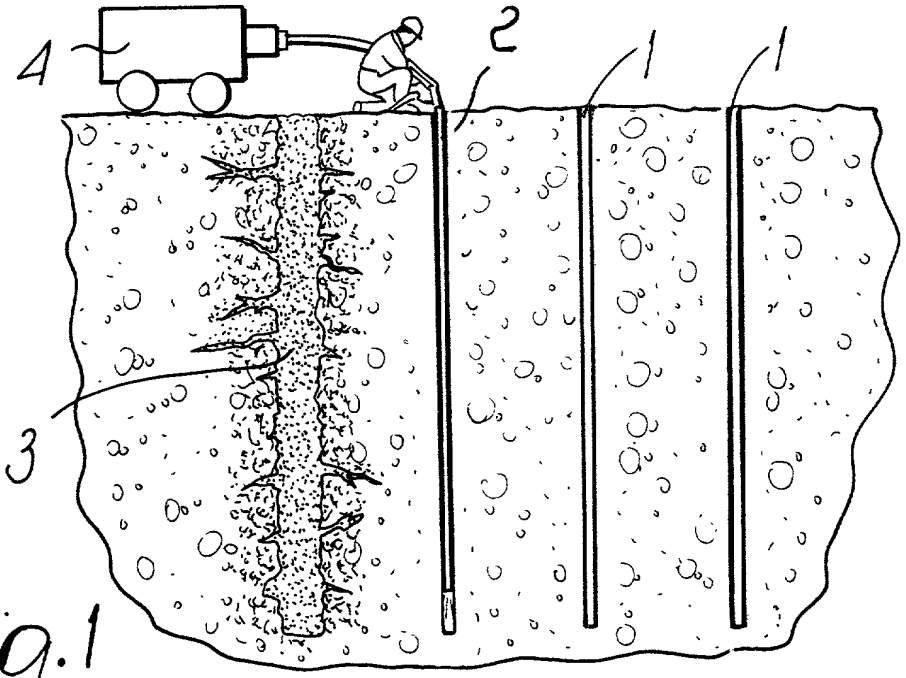


FIG. 1

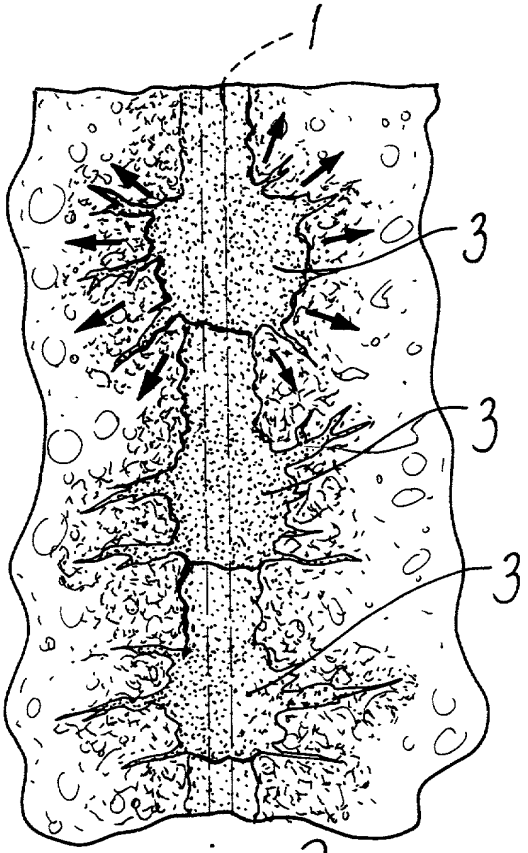


FIG. 2

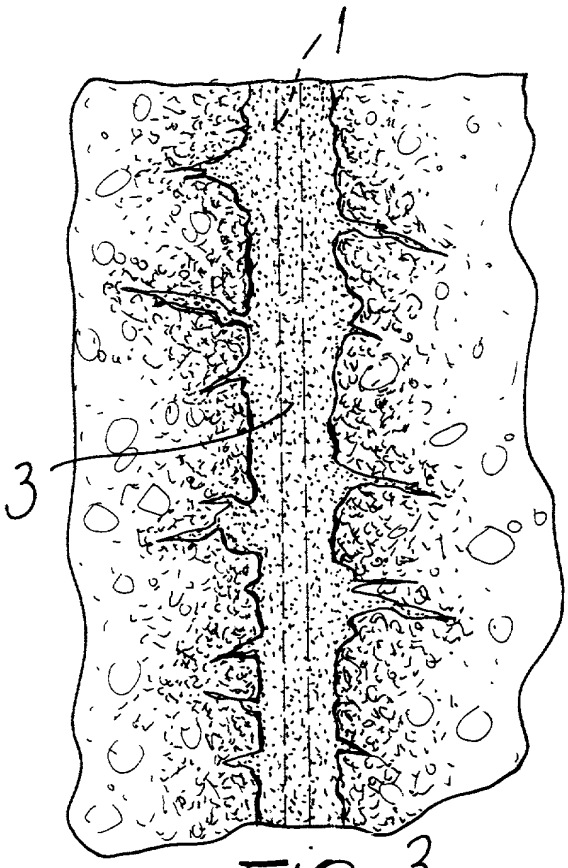


FIG. 3

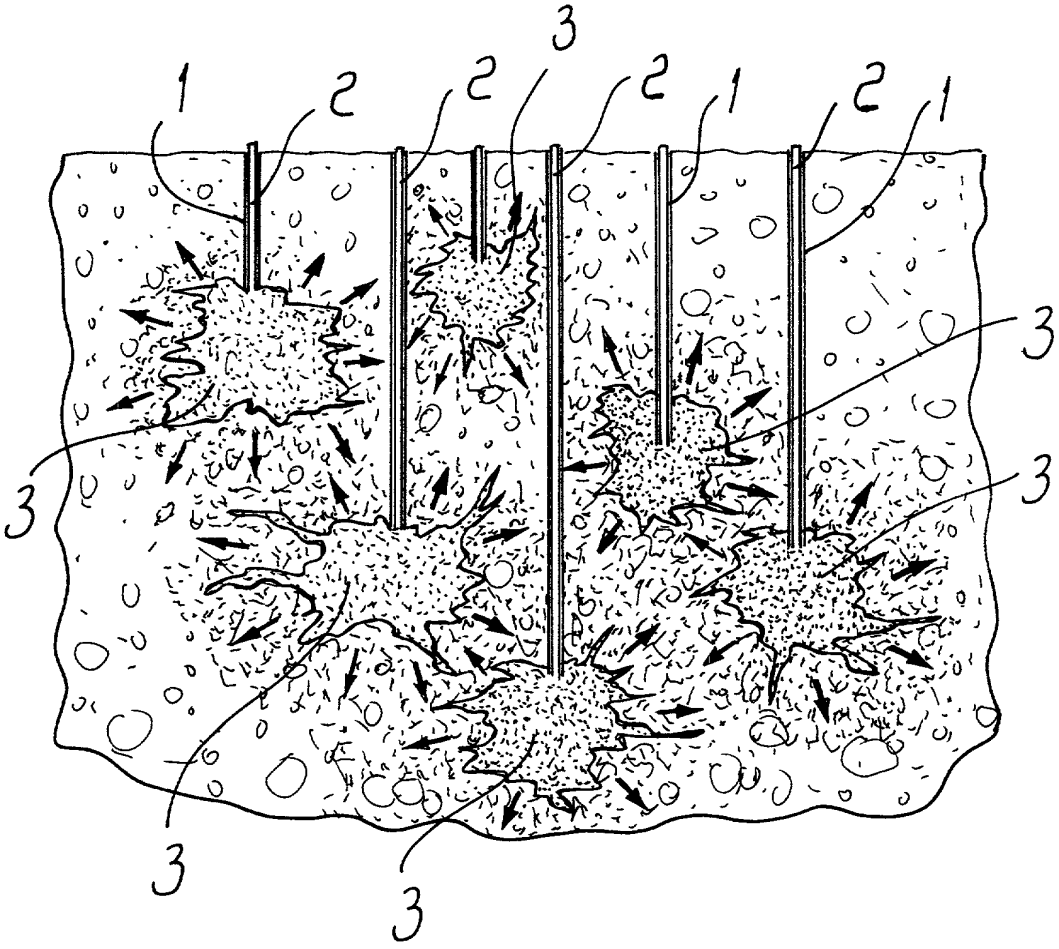


Fig. 4

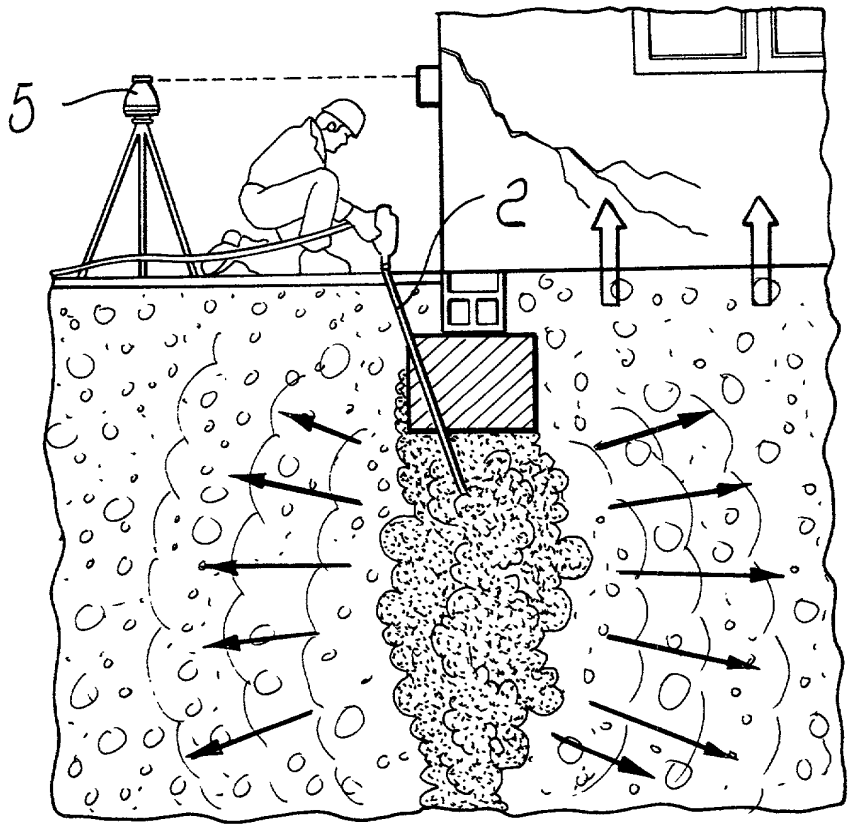


FIG. 5

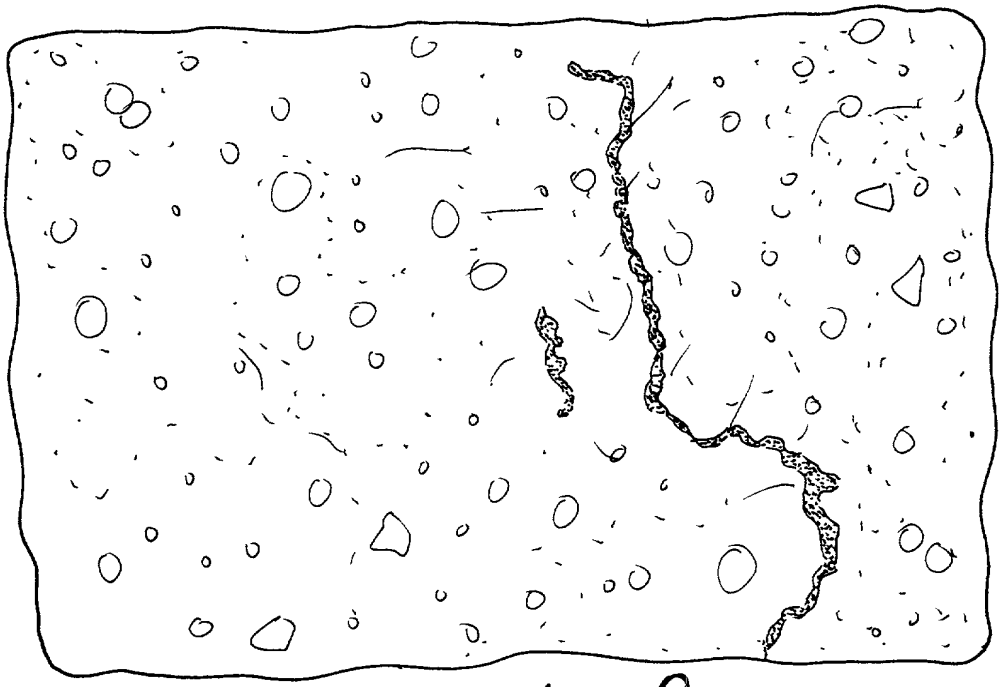
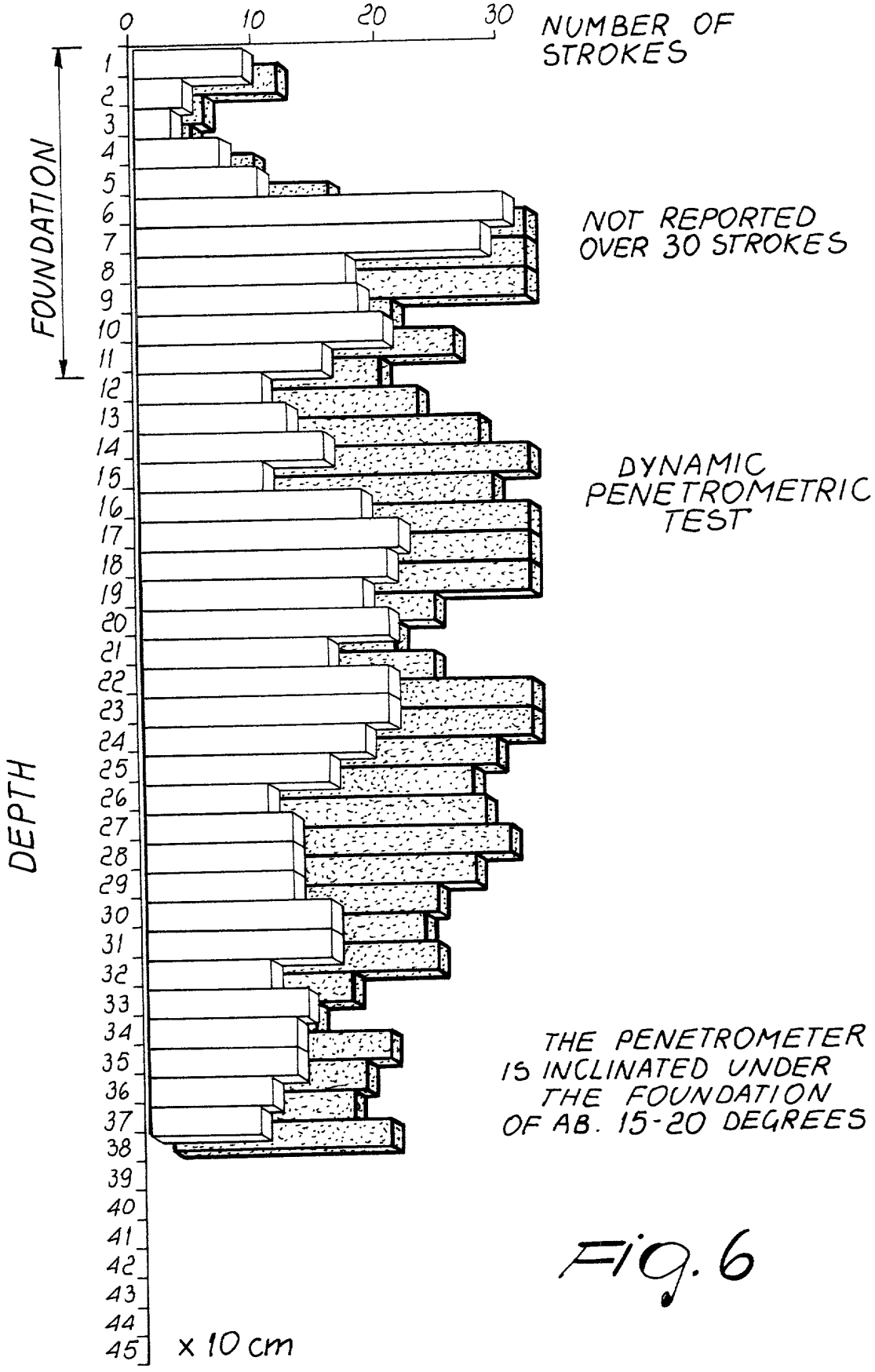


FIG. 9


0
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20
30
NUMBER OF STROKES
FOUNDATION
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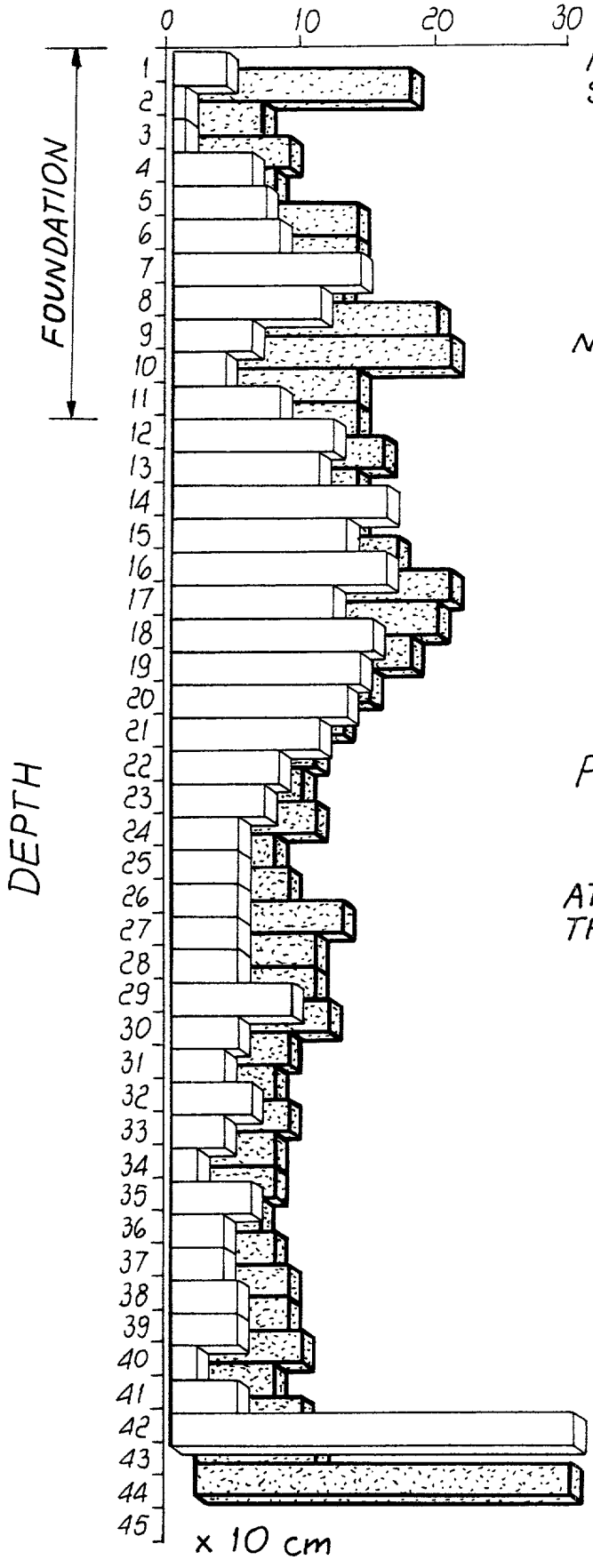
38
39
40
41
42
43
44
45
DEPTH
x 10 cm
NOT REPORTED OVER 30 STROKES
DYNAMIC PENETROMETRIC TEST
THE PENETROMETER IS INCLINATED UNDER THE FOUNDATION OF AB. 15-20 DEGREES

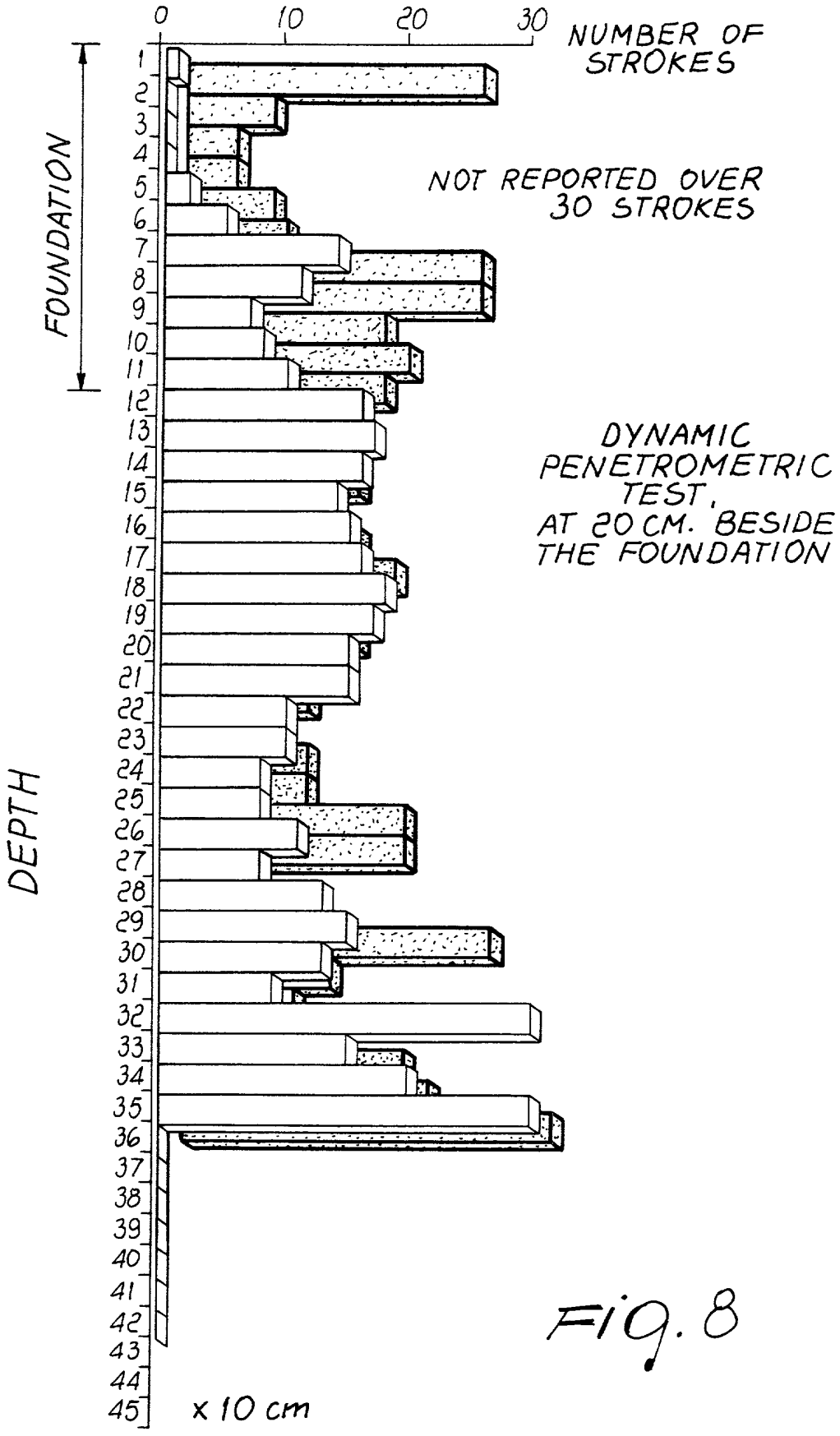
Fig. 6



DYNAMIC PENETROMETRIC TEST

AT 20 CM. BESIDE THE FOUNDATION

Fig. 7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20
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NUMBER OF STROKES
FOUNDATION
NOT REPORTED OVER 30 STROKES
DYNAMIC PENETROMETRIC TEST, AT 20 CM. BESIDE THE FOUNDATION
DEPTH
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45
x 10 cm

Fig. 8

POWER OF ATTORNEY

As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (*List name and registration number*)

Daniel J. O'BYRNE (Reg. No. 36,625)

SEND CORRESPONDENCE TO

MODIANO & ASSOCIATI
Via Meravigli, 16
20123 MILANO - ITALY
EUROPE

DIRECT TELEPHONE CALLS TO:
(*Name and telephone number*)

02-86 92 442

DECLARATION

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

SIGNATURE(S)

Full name of **sole or first inventor** Carlo CANTERI

Inventor's signature Carlo Canteri

Date August 24, 1999 Country of Citizenship Italy

Residence BRUNATE - ITALY ITX

Post Office Address Piazza Bonacossa, 12
22034 BRUNATE - ITALY

Full name of **second joint inventor**, if any _____

Inventor's signature _____

Date _____ Country of Citizenship _____

Residence _____

Post Office Address _____

Full name of third **joint inventor**, if any _____

Inventor's signature _____

Date _____ Country of Citizenship _____

Residence _____

Post Office Address _____

PATENT

Attorney's Docket No. 32431/DOB/1p

COMBINED DECLARATION AND POWER OF ATTORNEY

(ORIGINAL, DESIGN, NATIONAL STAGE OF PCT, SUPPLEMENTAL, DIVISIONAL, CONTINUATION OR CIP)

As a below named inventor, I hereby declare that:

TYPE OF DECLARATION

This declaration is of the following type: (*check one applicable item below*)

- [XX] original
- [ ] design

NOTE: If the declaration is for an International Application being filed as a divisional, continuation or continuation-in-part application do not check any of next two items and check appropriate one of last three items.

- [XX] national stage of PCT
- [ ] supplemental

NOTE: If one of the following 3 items apply then complete and also attach ADDED PAGES FOR DIVISIONAL, CONTINUATION OR CIP.

- [ ] divisional
- [ ] continuation
- [ ] continuation-in-part (CIP)

INVENTORSHIP IDENTIFICATION

WARNING: *If the inventors are each not the inventors of all the claims an explanation of the facts, including the ownership of all the claims at the time the last claimed invention was made, should be submitted.*

My residence, post office address and citizenship are as stated below next to my name, I believe I am the original, first and sole inventor (*if only one name is listed below*) or an original, first and joint inventor (*if plural names are listed below*) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

TITLE OF INVENTION

METHOD FOR INCREASING THE BEARING CAPACITY OF FOUNDATION SOILS FOR BUILDINGS

SPECIFICATION IDENTIFICATION

the specification of which: (*complete (a), (b) or (c)*)

(a) [ ] is attached hereto.

(b) [X] was filed on May 27, 1999 as [X] Serial No. 09/308,962
or [ ] Express Mail No., *as Serial No. not yet known* _____
and was amended on _____ (*if applicable*).

NOTE: Amendments filed after the original papers are deposited with the PTO which contain new matter are not accorded a filing date by being referred to in the declaration. Accordingly, the amendments involved are those filed with the application papers or, in the case of a supplemental declaration, are those amendments claiming matter not encompassed in the original statement of invention or claims. See 37 CFR 1.67.

(c) [XX] was described and claimed in PCT International Application No. PCT/EP97/06619 filed on November 27, 1997 and as amended under PCT Article 19 on _____ (*if any*).

ACKNOWLEDGEMENT OF REVIEW OF PAPERS AND DUTY OF CANDOR

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations. § 1.56(a).

[XX] In compliance with this duty there is attached an information disclosure statement. 37 CFR 1.97.

PRIORITY CLAIM

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed.

(complete (d) or (e))

(d) [ ] no such applications have been filed.

(e) [XX] such applications have been filed as follows

NOTE: Where item (c) is entered above and the International Application which designated the U.S. claimed priority check item (e), enter the details below and make the priority claim.

EARLIEST FOREIGN APPLICATION(S), IF ANY FILED WITHIN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO THIS U.S. APPLICATION

COUNTRY	APPLICATION NUMBER	DATE OF FILING (month, day, year)	PRIORITY CLAIMED UNDER 37 USC 119
ITALY	MI96A002520	2 December 1996	[XX] YES NO [ ]
			[ ] YES NO [ ]
			[ ] YES NO [ ]
			[ ] YES NO [ ]
			[ ] YES NO [ ]

ALL FOREIGN APPLICATION(S), IF ANY FILED MORE THAN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO THIS U.S. APPLICATION

_____

_____

_____

CHECK PROPER BOX(ES) IF ANY OF THE FOLLOWING ADDED PAGE(S) FORM A PART OF THIS DECLARATION

☐ Signature for third and subsequent joint inventors. *Number of pages added* _____

☐ Signature by administrator(trix), executor(trix) or legal representative for deceased or incapacitated inventor. *Number of pages added* _____

☐ Signature for inventor who refuses to sign or cannot be reached by person authorized under 37 CFR 1.47. *Number of pages added* _____

• • •

☐ Added pages to combined declaration and power of attorney for divisional, continuation, or continuation-in-part (CIP) application.

☐ Number of pages added _____

• • •

If no further pages form a part of this Declaration then end this Declaration with this page and check the following item

☒ **This declaration ends with this page**

#3

Docket No.: 32431/DOB/cb

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

Applicant : Carlo CANTERI

Assignee : PURE LIFE FOUNDATION

Serial No. : 09/308,962

Filed : May 27, 1999

For : "METHOD FOR INCREASING THE BEARING CAPACITY ..."

Group No. : still unknown

Examiner : still unknown

LETTER

ASSISTANT COMMISSIONER FOR PATENTS

BOX PCT

Washington D.C. 20231 - U.S.A.

To the kind attention of: Ms. Shelby Vigil,
National Stage Processing Paralegal Specialist

Sir,

In response to the NOTIFICATION OF MISSING REQUIREMENTS UNDER 35 U.S.C. 371 IN THE UNITED STATES DESIGNATED/ELECTED OFFICE mailed July 13, 1999 in respect of the above-identified Application, Applicant herewith submits, for completion of the Application papers already filed on May 27, 1999:

- Combined Declaration and Power of Attorney duly signed by the Inventor, Carlo CANTERI;
- Small Entity Verified Statement.

Authorization has already been given for the surcharge of US$ 65.00 required for entering the missing oath or declaration, to be charged to Deposit

Account No. 13-3860 of the firm MODIANO & ASSOCIATI, in the deposit account order accompanying the Application papers filed on May 27, 1999. This Authorization is hereby reiterated.

The Applicant herewith petitions the Commissioner of Patents and Trademarks to extend the time for response to the NOTIFICATION OF MISSING REQUIREMENTS UNDER 35 U.S.C. 371 IN THE UNITED STATES DESIGNATED/ELECTED OFFICE dated July 13, 1999 for one month from August 13, 1999 to September 13, 1999. Please charge Deposit Account No. 13-3860 of the firm MODIANO & ASSOCIATI, in the amount of US$ 55.00 (fee code 215) to cover the cost of the extension. Any deficiency or overpayment should be charged or credited to the above numbered deposit account.

A duplicate copy of this communication is enclosed.

Moreover, since the small entity declaration is being filed within the time limit, we presume that no surcharge is due in this respect.

A copy of the Notification of Missing Requirements is also herewith attached.

Respectfully submitted

Daniel J. O'BYRNE
Agent for the Applicant
(Reg. No. 36,625)

Milan, August 27, 1999